Electro-Chemically Enhanced Mechanical Polishing of Nickel Mandrels

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Electroformed Nickel Replication

- For the x-ray mirror fabrication, an electroformed nickel replication (ENR) process is being developed at MSFC. In this, nickel alloy mirror shells are electroformed onto a figured and superpolished nickel plated aluminum mandrel from which they are later released by differential thermal contraction.

- This process, pioneered in Italy for x-ray mirror fabrication, has been used for soft-x-ray astronomy in such missions as XMM-Newton.

- The resulting full shells are inherently stable and thus can provide good angular resolution.

Angular Resolution Errors

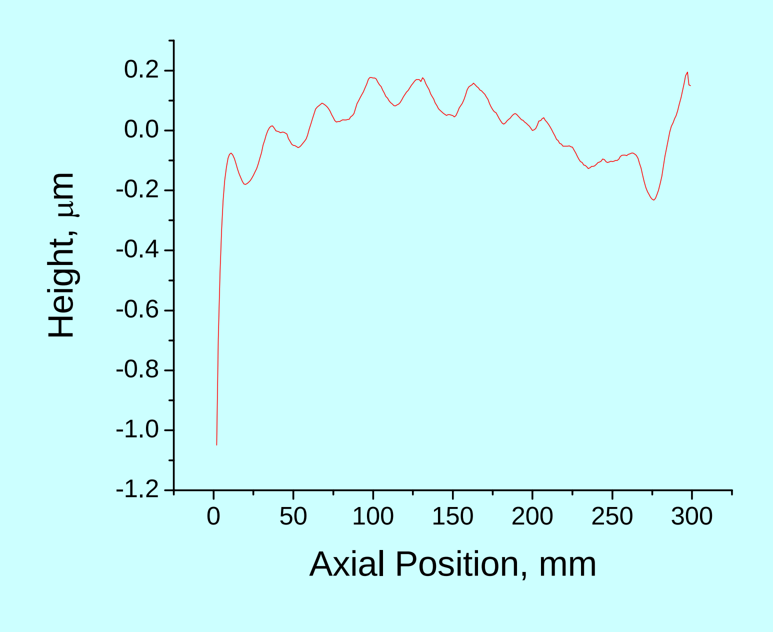
- The average axial sag and the axial slope, are the dominant contributors to the error budget.

- The average axial figure sag represents the departure of the mandrel figure from the perfect Wolter-1 shape (5-6 arc sec HPD).

- The mid-frequency axial slope is a measure of the mm- to cm-scale variations in the axial figure of the replicated shell (~10 arc sec HPD).

- These variations may be present in the mandrel and carried over through replication, or may come about during electroforming of the shell.

Mid-frequency Errors (Mandrel)



- The mechanical polishing as mandrel fabrication technique inherently leads to mid-frequency ripple on the mandrel surface.

- Typically the mandrel has mid-frequency figure variations at the 100-nm level.

Height profile of the parabolic section for the 68 mm diameter mandrel, measured using the VLTP.

Electrochemically Enhanced Mechanical Polishing

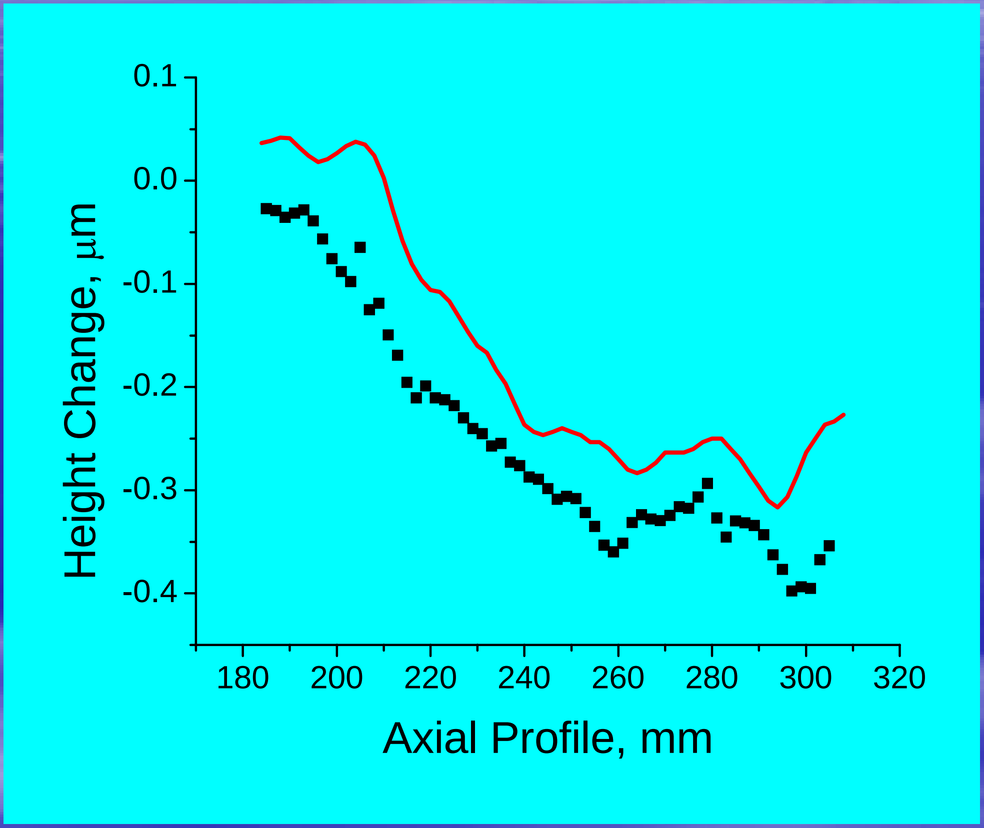
- It is known that an applied electrical current and the use of an appropriate electrolyte will etch essentially all conductive and semi-conductive materials. By placing the electrode above high spots on an optical surface and applying an electric current, the process can be used for figure correction.
- If the electrochemical etching is combined with mechanical polishing, with the polishing compound added to the electrolyte, the figuring and the surface finishing can be done simultaneously.

- Small flat samples were polished to 5 A rms roughness. Then, the disk surface was partially masked and the unmasked portion of the surface was mechanically polished with constant electrical current applied.
- Using this technique the electrolyte chemistry, the electrical current and polishing compounds and materials were optimized to control the processes of etching, polishing and oxide formation.
- The electrochemical mechanical polishing method allows *selective* removal of nickel phosphorous alloy with rate up to 0.5 micron per minute *without* surface microroughness degradation (for samples with ~ 5 A rms microroughness).

Electrochemically Enhanced Mechanical Polisher

600- mm long, 44-mm diameter x-ray mirror mandrel on the electrochemically enhanced mechanical polisher

Mandrel test



Difference in the height of the mandrel profiles after and before EEMP. The solid line represents the normalized electric current applied.

Summary

- The electrochemically enhanced mechanical polishing aims to reduce the mid-frequency mandrel figure ripple with the ultimate goal of a quick and inexpensive way to figure high-precision Wolter-1 mandrels.

- We have demonstrated that the method allows selective removal of material from the mandrel while preserving the microroughness of the surface.

- A computer-controlled polisher, which utilizes the EEMP approach, has been built and HERO test mandrels are planned to be polished in near future to demonstrate the approach.